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The Punitive Effect of Electric Shock in Rats in Relation to the Rate of Food Reinforcement

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Punishment has been defined as the process by which a consequence of behavior reduces the future probability of that behavior (Azrin & Holz, 1966). In the procedure known as positive punishment, the consequence is presented contingent on the response. In basic experimental research with animal subjects, the stimulus that is used as the punishing consequence is typically electrical shock. In these experiments, response rates in conditions with and without punishment are compared. Initially, responding is reinforced with food to establish a baseline level of responding. Once baseline response rates stabilize, a schedule of shock punishment is superimposed on the schedule of food reinforcement. The punitive function of the shock is measured in terms of the difference in response rates across the conditions.

Multiple variables that are important to the study of punishment have been identified in the literature. The exact effects of these variables, however, is not fully understood.

Researchers have manipulated the intensity of the electric shock used as the punishing stimulus because it can be manipulated over a wide range (Azrin & Holz, 1966). This flexibility allows for a parametric examination of the effects of punishment. In an early study, Azrin (1960) examined the effects of varying the intensity of shock on the punitive effect of the shock. Key pecking of six pigeons was reinforced by 3-s access to food according to a variable-interval (VI) schedule. In a VI schedule, a reinforcer is produced following the first response that occurs after an averaged specified period. Some pigeons were trained with a VI 60-s schedule and others with a VI 360-s schedule, however, Azrin did not analyze the effects of reinforcement rate. After this baseline was established, a fixed-ratio (FR-1) schedule of shock was introduced. The shocks were brief (30 or 100 ms depending on the pigeon) and the intensities were manipulated across four conditions, ranging from mild shock (30 V) to severe shock (130 V for 100 ms or 70 V for 300 ms). Across all conditions, response rates were initially suppressed. During mild shock conditions, response rates eventually recovered to baseline levels in subsequent sessions. Conversely, during severe shock conditions, response rates were almost completely suppressed in all subsequent sessions. This study showed that there was a direct relationship between the intensity of shock and the punitive function of the shock.

Holz (1968) conducted a study with pigeons in which key pecks were reinforced according to a VI 1.9-min schedule of food reinforcement on the left key and a VI 7.5-min schedule on the right key. After baseline responding stabilized, an FR-1 schedule of shock was added to both keys. Across conditions, the intensity of shock was raised from 3 mA to 12 mA. As shock intensity was raised, responding on both keys decreased. Absolute response rates were higher during the rich schedule of reinforcement, across all punishment intensities. However, proportional suppression was independent of reinforcement rate.

Walters (1978) studied the effects of the rate of reinforcement on response suppression. Across 40 baseline sessions, seven rats were reinforced with food according to a VI schedule. The rate of reinforcement was manipulated across a range of 0.25, 0.5, 1, and 4 pellets per minute. During punishment conditions, an FR-1 schedule of shock delivered 0.2 mA shocks for 100 ms. For all rats, the rate of responding was directly related to the rate of reinforcement in baseline and punishment conditions. However, reinforcement rate did not have an effect on the degree of suppression during punishment.

Church and Raymond (1967) evaluated the effect of shock on rats' rate of lever pressing on rich and lean schedules of food reinforcement. During baseline, half of the rats responded on a VI 5-min (lean) schedule and the other rats responded on a VI 0.2-min (rich) schedule. During punishment components, a VI 2-min schedule of shock (.15 mA for 2 s) was superimposed on the VI schedule of food reinforcement. The punitive effect of shock was inversely related to the rate of reinforcement. On the lean schedule, shock almost completely suppressed responding. On the rich schedule, shock suppressed responding to a lesser degree.

There were differences in the rate of reinforcement across the studies. Holz (1968) used rates of reinforcement of 0.13 and 0.53 pellets per minutes, Church and Raymond (1967) used 0.2 and 12 pellets per minute, and Walters (1978) used a range from 0.25 to 4 pellets per min. Walters (1978) noted that rats in the rich schedule of reinforcement in Church and Raymond's (1967) experiment showed steady increases in response rates throughout training sessions and did not reach stability before moving to punishment conditions. It is possible that if the baseline rates of responding were run until stability in the Church and Raymond (1967) study, different results could have been obtained.

In addition to the difference in rates of reinforcement, there were also methodological differences that preclude a full comparison between these studies. While Holz (1968) and Walters (1978) delivered shock according to an FR-1 schedule, Church and Raymond (1967) delivered shock according to a VI 2-min schedule. These differences are important because the schedule of punishment is likely to interact with the rate of reinforcement. There were also differences in the schedules of food delivery across the studies. Holz (1968) and Church and Raymond (1967) delivered food according to concurrent VI schedules while Walters (1978) delivered food according to simple VI schedule. This is important because differences in the allocation of behavior may interact with the effectiveness of the punisher. Because of parametric and methodological differences between the three studies just described, further study of the effect of the rate of reinforcement on punishment is warranted.

The purpose of the present experiment was to examine effects of the rate of reinforcement on the punitive function of shock. In baseline conditions, rats' lever presses were reinforced with food according to a VI schedule. During punishment conditions, a VR-5 schedule of shock punishment was superimposed on the VI schedule. Across pairs of baseline and punishment conditions, the rate of reinforcement ranged from 0.5 to 6 food deliveries per min. Measurement of the punitive function of shock was based on comparisons of the response rates in baseline and punishment conditions.

Method

Subjects

Four male albino Sprague Dawley rats with previous lever-press training were housed in pairs under a 12:12 hr reversed light/dark cycle in a temperature-controlled room. Experimental sessions were conducted during the dark period. The rats were maintained at 80% (±2%) of their free-feeding body weights. During sessions, grain-based food pellets were delivered as reinforcers. Grain based chow was provided as necessary at least 30 min after sessions. Water was freely available in the home cage. The treatment of the rats, in and out of the experimental sessions, complied with a protocol approved by the West Virginia University Animal Care and Use Committee.

Apparatus

Sessions were conducted in four operant-conditioning chambers enclosed in ventilated sound-attenuating chests (Med Associates Inc., St. Albans, VT). The interior of each chamber was 29 cm long, 22 cm high, and 24 cm deep. The ceiling and sidewalls were constructed of Plexiglas, and the end walls of stainless steel. The floor consisted of 19 stainless-steel rods 0.5 cm in diameter, spaced approximately 1.3 cm apart (center to center). On the front wall were two retractable levers. Each lever was 4.4 cm wide, 1.3 cm thick, and protruded 1.9 cm into the chamber when inserted. The inside edges of the levers were spaced 11.4 cm apart (5.7 cm from the middle of the wall). The tops of the levers were positioned 8 cm from the floor. An audio speaker was located behind the back wall. Food pellets (45-mg, BioServ) were delivered into a magazine centered on the front wall. Each pellet was accompanied by a 12-Hz tone lasting 1 s. Scrambled shock was delivered to the grid floor by a constant-current shock generator (Med Associates ENV-413). General illumination was provided by a houselight (No. 1820 bulb) located on the back wall. White noise (80 dB) masked extraneous sounds. Experimental events were controlled and recorded with computers connected to the chambers via digital interfaces (Measurement Computing, model PCI-PDIS08).

General Procedure

Sessions were conducted seven days per week at approximately the same time each day. After the rat was placed in the chamber, a 5-min delay preceded the start of the session to allow the rat to recover from any effects of handling. During this delay, all chamber lights and sounds were off and both levers were retracted. Sessions began with the illumination of the houselight, onset of the white noise, and the insertion of the lever into the chamber.
The houselight remained lit throughout the entire session. Each session ended after 60 reinforcers were delivered or after 4 hr had elapsed.

Experimental Conditions

Table 1 shows the experimental conditions for each rat, which were arranged in pairs. In the baseline condition of each pair, food was delivered according to a VI schedule. In the punishment condition of each pair, a VR-5 schedule of shock was superimposed on the VI food schedule. These VI and VR schedules operated simultaneously, therefore, a single lever press could satisfy both schedules simultaneously. In such cases, the response produced a food pellet and was not counted toward the VR schedule of shock. The VI schedule – and then the rate of reinforcement – were manipulated across the pairs of conditions. The VI schedules had mean durations of 10 s, 15 s, 30 s, and 120 s, which respectively yielded mean reinforcement rates of 6, 4, 2, and 0.5 pellets per min. Over the course of the first punishment condition, the intensity and duration of shock were adjusted for each rat until the response rate in the shock condition was about 50 percent of the rate in the baseline condition. Final shock parameters for each rat were as follows: 0.2 mA, 200 ms (VT11), 0.25 mA, 300 ms (VT12), 0.35 mA, 200 ms (VT13), 0.6 mA, 150 ms (VT14). Once the shock parameters were fixed, baseline conditions lasted 10 sessions and punishment conditions lasted 5 sessions.

Results

The left column of Figure 1 shows response rates as a function of reinforcement rate for each rat. The results are the means (+/- 1 SD) for each condition, averaged over the last 3 sessions. Response rates during the baseline and punishment conditions generally increased as the reinforcement rate was raised for two out of four rats (VT12, VT13). For one rat (VT11), response rates during baseline decreased as the pellet delivery rate increased. During punishment conditions, responses per minute increased as the rate of reinforcement increased. For the other rat (VT14) baseline response rates generally increased as pellet delivery rate increased. For this rat, responses per minute generally decreased as the rate of reinforcement increased during punishment conditions.

The difference in responding across the baseline and punishment conditions can be summarized by the suppression ratio, a measure that expresses responding in the punishment condition relative to the baseline condition. The right panel of Figure 1 shows suppression ratios as a function of the pellets delivered per minute for each rat. The suppression ratios were calculated for each pair of conditions with the following formula:

$$\text{Supression Ratio} = \frac{\text{Resp. Rate (Punishment)}}{\text{Resp. Rate (Punishment)} + \text{Resp. Rate (Baseline)}}.$$

Response rates were from the last 3 sessions of each condition. The right panel of Figure 1 shows the mean (+/- 1 SD) of these ratios. The dotted line on each individual graph indicates suppression ratio values at 0.5. Data points below this line, indicate that responding in the punishment component was lower than responding in the baseline component, showing a punitive effect of shock.

For three rats (VT11, VT12, and VT13) suppression ratios decreased as the rate of reinforcement increased. For one rat (VT14), the relationship between the suppression ratio and the rate of reinforcement was less clear. For this rat, suppression ratios initially decreased as the rate of reinforcement was increased, however, this trend was not maintained.

Discussion

This experiment investigated the punitive effect of shock as a function of the rate of reinforcement. For some rats, shock became less punitive as the rate of reinforcement increased.

These results support Church and Raymond's (1967) finding that the punitive effect of shock decreased as the rate of reinforcement was raised. However, in their study, only two reinforcement rates were evaluated. By using a small range of reinforcement rates, no functional relations between reinforcement rate and the punitive effect of shock can be established. It is possible that reinforcement rates beyond the range used in this study would yield different results. Future research evaluating a greater range of reinforcement rates could help us better understand the interaction between reinforcement rate and the punitive effect of shock.

Walters (1978) found that the punitive effect of shock did not change significantly across reinforcement rates. These results are inconsistent with the results of the present study even though Walters used reinforcement rates similar to those used in the present study: 0.25 to 4 pellets per minute versus 0.5 to 6 pellets per minute in the present study. There were other methodological differences that might be responsible for the difference in results. In Walters' study, a shock (0.2 mA, 100 ms) was delivered after each lever press. In the present study, a VR-5 schedule of shock was used. It is possible that the differences in the schedule of shock delivery altered the punitive effect of shock.

Procedural restrictions limit the implications of the present study. One restriction was that punishment components for each condition lasted only 5 sessions. Because the amount of sessions was fixed, responding was not able to reach stability. It is possible that if response rates reached stable levels during punishment conditions, the suppression ratios could be different. Additionally, the present study only evaluated the punitive effect of shock at two or three reinforcement rates per rat. Some rats were not evaluated at the leanest reinforcement rate and other rats were not evaluated at the richest reinforcement rate. Evaluating a wider range of reinforcement rates could help us deepen our understanding of the effectiveness of punishment overall.

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Table 1. Variable-interval schedule, reinforcement rate, and presence of shock for each condition. The conditions are shown in the order of their presentations for each rat.

Rat	Condition	VI (s)	Pellets per min	VR-5 shock
VT11, VT14	Baseline	30	2	No
	Punishment	30	2	Yes
	Baseline	15	4	No
	Punishment	15	4	Yes
	Baseline	10	6	No
	Punishment	10	6	Yes
VT12	Baseline	30	2	No
	Punishment	30	2	Yes
	Baseline	120	0.5	No
	Punishment	120	0.5	Yes
VT13	Baseline	30	2	No
	Punishment	30	2	Yes
	Baseline	120	0.5	No
	Punishment	120	0.5	Yes
	Baseline	15	4	No
	Punishment	15	4	Yes

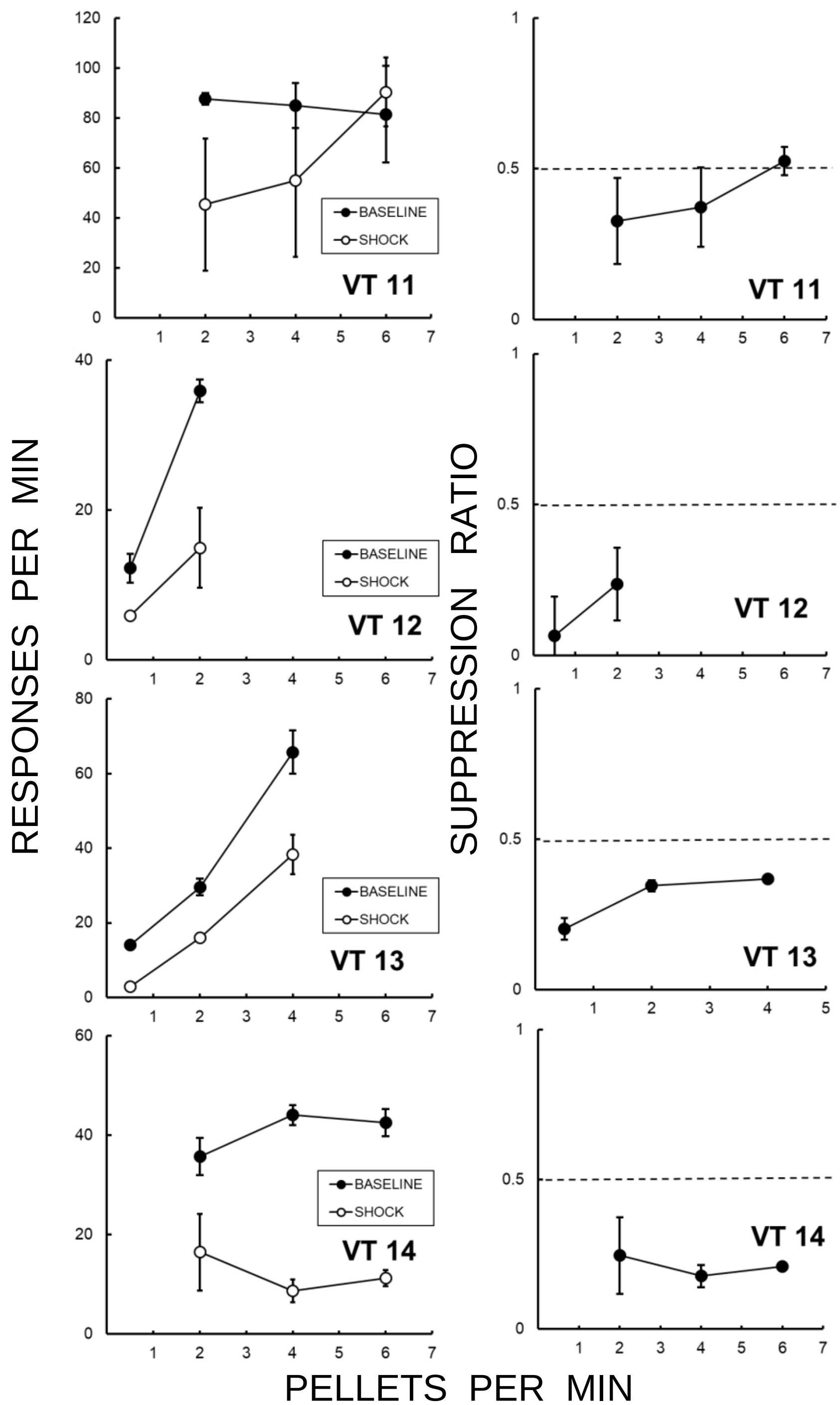

Figure 1. Mean responses per minute (left column) and mean suppression ratios (right column) from the last 3 sessions of each condition. All error bars are extended 1 SD above and below the mean.